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Review

Failure analysis of drill pipe: A review

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ABSTRACT

Although the drill pipe is a simple tool in the drilling industry, it is the most used and important one. The drillstring failure has two general forms: wash-out and twist-off. These failures begin with mechanical, thermal and corrosion fatigue cracks. On the basis of previously conducted researches, the failure of drillstring is not unknown. However, the occurrence of drillstring failure still is too much. The main reason for this can be due to complex loading, combined stresses and different types of vibrations and moreover, the corrosive and erosive behavior of drilling mud that makes the total condition of the well so difficult to analyze. In this paper, the attention is focused on the analysis of drill pipe failure and the fatigue crack is represented for the root cause of drill pipe failure. The aims of most of published papers are to examine how and why a specific drill pipe is failed and just the main reason of failure for that drill pipe is discussed in detail. In this paper all metallurgical and mechanical aspects of failure that can occur for a drill pipe, are considered and discussed. And finally, this comprehensive review leads to a conclusion that categorizes the primary sources of drill pipe failure into seven major groups and makes some recommendations to avoid them.

Contents

1. Introductions

Drilling a gas or oil well, costs tens of million dollars. A huge amount of money is spent daily on a rig to provide mud materials, cement, diesel and food stuff as well as renting a wide variety of tools and charging different service companies. The occurrence of a downhole failure in drillstring interrupts the whole operation and it takes time to retrieve the remained downhole parts called “fish”. In some cases, the rig crew are incapable of fishing[1] and they have to perform sidetracking operation to get

Abbreviations: H.W.D.Pheavy weight drill pipe; W.O.Bweight on bit; R.P.Mrevolution per minute; GPMgallon per minute; R.O.Prate of penetration; BHAbottom hole assembly; APIAmerican Petroleum Institute; AISIAmerican Iron and Steel Institute; ISOInternational Organization for Standardization; SEMscanning electron microscopy; EDSenergy dispersive spectroscopy; SSCsulfide stress cracking; SCCstress corrosion cracking; HIChydrogen induced cracking; SCFstress concentration factor; $K_t$stress concentration factor; DLSdogleg severity; Incinclination; MWDmeasurement while drilling; LWDlogging while drilling; *D*pipe body outside diameter; *d*pipe body inside diameter; d_{ou}drill pipe upset inside diameter; D_{ou}drill pipe upset outside diameter; M_{iu}drill pipe internal upset taper length; L_{iu}drill pipe internal upset length; M_{eu}drill pipe external upset taper length; L_{eu}drill pipe external upset length

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[1] - the act of recovering a downhole fish

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to the last drilled depth. These operations sometimes can last for several months and the companies will sustain heavy financial losses due to this waste of time. In addition, the cost of damaged and unrecovered parts can add to the problem. Accordingly, as it can be easily seen, the drillstring failure is an unpleasant incident in the drilling industry.

On the basis of previously conducted researches, the failure of drillstring is not unknown. Against significant progresses in downhole tools manufacturing to improve the load capacity of drillstring elements, reduce the torque and forces and software analysis to calculate and predict them, the occurrence of the drillstring failure still is too much. The main reason for this can be due to complex loading, combined stresses and different types of vibrations and moreover, the corrosive and erosive behavior of drilling mud that makes the total condition of the well so difficult to analyze.

The operation of drilling progresses with the rotation of the bit while the drilling mud is pumping through the drillstring to the bottom of the hole to cool and lubricate the bit as well as cleaning the wellbore by transferring cuttings to the surface. The drilling mud can provide the required hydrostatic pressure at the drilling depth.

Although the drill pipe is a simple tool in the drilling industry, it is the most used and important one. Drill pipes make a significant portion of the drillstring. While working, complex loadings such as tension, compression, torsion, bending, hydrostatic pressure and vibrations are acting on the drill pipe. Quantity, position and inducing time of these loads are not constant and are always changing. In addition, loads and stresses will be more different and complicated in deviated wells where the probability of failure rises by the falling of fatigue strength.

Failures commonly can be seen on four places of a drill pipe: at the threaded connections, on the inside surface of the drill pipe, on the outside surface of the drill pipe body and the upset area.

The drillstring failure has two general forms: wash-out and twist-off. These failures are considered to begin with mechanical and corrosion fatigue cracks [1]. The wash-out refers to a small opening on the seamless drill pipe body caused by different reasons, especially fatigue crack growth and the term twist-off refers to the complete separation of the drill pipe. Fatigue cracks usually initiate from highly localized stress concentration points [1].

The most researchers followed the same study procedure. At first, they had some visual observations on failed drill pipes. The fracture surface and the internal and external surfaces of damaged drill pipes were carefully examined and surface defects were reported. Optical microscope and SEM were used for metallurgical examination and fractography to reveal the microstructure and different phases as well as crack sources and fracture type. In some cases, the chemical composition was analyzed. Meanwhile, the charpy impact and tensile test were conducted and the hardness was measured as well. All of these results were compared with API Spec 5DP to satisfy the mechanical properties requirements.

2. Mechanical review of failure

Drillstring is under some heavy and complex dynamic loadings. There are some weak points on the drill pipe where the stress concentration is much higher than other parts of the drill pipe. These places have a good potential for initiating crack. Stress concentration points in a drill pipe can be divided into four main groups:

1) Surface irregularities
2) Upset area
3) Corrosion pitting
4) Threaded connections

Surface irregularities are macro and micro surface defects on drill pipe body caused by inappropriate handling, incorrect operational use and the most important, slip-cuts. Fig. 1 shows a typical wash-out due to slip-cuts. In the drilling industry, these points are well-known as the fatigue crack initiation sites [1–5]. The effect of dies of gripping systems on fatigue of drill pipe in a deviated well has been studied in several research works by M.K.Rahman et al. [3,4].

Fig. 1. Slip-cuts on 5″ DP resulting in a wash-out.